CRUISE MISSILES

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CRUISE MISSILES*

ISSUE DEFINITION

A remarkably versatile and controversial weapon has become familiar on the world military stage in the past decade and a half. Although the cruise missile concept is not new, the modern cruise in its various forms is a striking departure in weapons technology and its full impact on military strategy and arms control is still not well understood.

In the late 1970s and early 1980s, debate over the cruise focused on its implications for the U.S.-Soviet military balance. Proponents contended that this weapon was relatively inexpensive, and could therefore be deployed in large numbers; that it would conserve sophisticated aircraft and skilled men in the increasingly hostile air environment of the modern battlefield; and that the air-launched cruise would offset the declining effectiveness of U.S. strategic bombers. Opponents argued that this readily-concealable weapon would destabilize the strategic balance; that the cruise enormously complicated arms reduction negotiations; that it was neither as inexpensive nor as reliable as adherents claim; that U.S. deployment of a new strategic weapon forced the U.S.S.R. to follow suit, escalating the arms race; and that changes were being made in U.S. force structure before the operational role of cruise missiles had been adequately defined in military doctrine. In the case of Canada, peace activists and others opposed the Canadian government decision to allow the testing of U.S. air-launched cruise missiles in northern Canada.

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* This paper is based on work originally done by Dean Clay. For a discussion of arms control issues, see Current Issue Review #87-13E, "Arms Control and Disarmament," Research Branch, Library of Parliament.

With the end of the Cold War and the decline of the "Soviet threat," critics argued that cruise missiles had outlived their usefulness. In early 1991, conventionally-armed cruise missiles saw action in the Gulf War, and proponents argued that the cruise was ideal for lower-level conflicts in "out of area" locations. In April 1992, MIT physicist Kosta Tsipis argued in *The New York Times* that, despite the much-discussed proliferation of ballistic technology, accurate cruise missiles could be a much greater threat in the future. According to Tsipis, basic cruise technology in the form of commercial jet engines, gyroscopes and autopilots is now widely available to anyone who wants it. In his words, "Any country that can manufacture simple aircraft can construct a cruise missile that can carry a ton of cargo at least 300 miles and land no more than 30 feet from its target." This may perhaps mark the direction of future debates over cruise missiles.

BACKGROUND AND ANALYSIS

A. Cruise Missile Development

While there is sometimes confusion about what is or is not a cruise missile, it is basically an expendable, unmanned, self-guided, aerodynamic vehicle continuously powered by an air-breathing jet engine. It can be armed with a small, high-yield nuclear warhead, a conventional high-explosive warhead, or a submunitions package for such specialized tasks as runway cratering. In its various tactical and strategic roles, the cruise can be launched from aircraft, submarines, ships or mobile launchers on land against many types of targets.

Although the cruise missile concept dates back to World War I, when experimentation began with drone aircraft, the operational history of the cruise really began with the German introduction of the V-1 jet-powered flying bomb in World War II. Building upon German technology, both the United States and Soviet Union developed tactical (short-range) cruise missiles with crude guidance systems during the 1950s. The U.S. also deployed longer-range winged missiles with its strategic forces, but these proved unreliable in their guidance and difficult to maintain.

With the appearance of the Killian Report in 1955, which presented alarming evidence of Soviet ballistic missile development, with the first successful Soviet test of an ICBM (intercontinental ballistic missile) in August 1957, and with the launching of Sputnik in October 1957, many American strategists concluded that the Soviet Union held a substantial lead in ballistic missilery. ICBM development was accorded high priority in the U.S., and long-range cruise missile development languished. The Soviet Union, however, continued throughout the 1960s and 1970s to modify and upgrade its tactical cruise missile suites, emphasizing naval missions as a countervailing threat to U.S. aircraft carrier task forces. (It was a Soviet antiship cruise missile, the Styx, which Egyptian forces used to sink an Israeli destroyer during the 1967 war. The U.S. used its short-range anti-ship missile, The Harpoon, against Libyan patrol boats in 1986.)

U.S. interest in cruise missiles re-emerged in the 1970s. Advancing technology in the form of improved guidance, miniaturized electronics, small turbofan engines, high-energy propellants, high-yield conventional and nuclear warheads in compact configurations, and airframes with reduced radar detectability promised the effective application of cruise weapons, even measured against evolving rocket-powered weaponry.

The history of the modern strategic cruise missile in effect began in 1972 when the U.S. Secretary of Defense requested $20 million for the Navy to design a submarine-launched missile with a strategically significant range. In 1974, the U.S. Navy was directed to develop a sea-launched cruise capable of both strategic and tactical missions. During this period, the U.S. Air Force had conducted bomber penetration studies which would lead to a proposal for an air-launched strategic cruise missile. To enhance the survivability of the relatively slow B-52 strategic bomber in penetrating Soviet air defences, the U.S. had in 1969 initiated the subsonic cruise armed-decoy program, SCAD, while simultaneously developing a short-range attack missile, SRAM, to provide the B-52 with some capability to suppress air defences. The idea then arose of using strategic bombers to launch missiles from a standoff position and work started on a strategic air-launched cruise in 1974, carrying on from the SCAD program. With the establishment of the Joint Cruise Missiles Project in 1977, development of an Air Force air-launched cruise missile (ALCM), a Navy sea-launched cruise missile (SLCM),

and an Air Force ground-launched cruise missile (GLCM) carried forward in a coordinated program.

A 1979 fly-off between the Boeing and General Dynamics versions of the ALCM led to Boeing being chosen to continue with the nuclear-armed air-launched cruise, to be installed on B-52 and later B-1B bombers. General Dynamics subsequently won a contract to produce three versions of a "Tomahawk" SLCM: a land-attack missile armed with a nuclear warhead in one variant and a conventional warhead in the other, and a conventionally-armed antiship missile. General Dynamics also won the contract for a nuclear-armed GLCM, later deployed by NATO in Western Europe.

In an attempt to take advantage of the production capabilities built up by Boeing and General Dynamics, the Air Force and the Navy were directed to pursue jointly the development of a medium-range (about 560 kilometres) air-to-surface missile (MRASM), designed to be a conventionally-armed tactical version of the ALCM. General Dynamics was eventually chosen to develop the MRASM based on the design of the Tomahawk, but both variants (AGM-109H and AGM-109L) were cancelled in development. The remaining versions of the cruise, one form of the Boeing, an advanced missile designed to replace it and variants of the General Dynamics Tomahawk, can be itemized as follows:

- the Boeing air-launched nuclear-armed cruise (designated AGM-86B), designed to be fired from B-52 or B-1 strategic bombers. In early 1992, it was revealed that a small number of ALCM's had been converted to conventional missiles, armed with high-explosive warheads and able to use the US Global Positioning System (GPS) for guidance by 1988. Thirty-five of these AGM-86Cs saw action in the Gulf War of 1991.
- the Advanced Cruise Missile (ACM) designated AGM-129A; this missile incorporated "stealth" technology, was of longer range and higher speed than the AGM-86B, which it was designed to replace. The production of this missile was cancelled in January 1992 at the level of 640 missiles planned by that date.
- the General Dynamics ground-launched nuclear-armed cruise (designated BGM-109G); this missile was eliminated under the 1987 Intermediate-Range Nuclear Forces (INF) agreement.
- General Dynamics sea-launched cruise variants:

-- a nuclear-armed land-attack version (BGM-109A);

-- a conventionally-armed antiship version (BGM-109B);

-- a conventionally-armed land-attack version (BGM-109C), which is known as BGM-109D when it carries a submunitions package for such tasks as cratering runways.

ALCMs were first deployed at Griffiss Air Force Base in New York in 1982, using a squadron of 16 Boeing B-52s of the Strategic Air Command as the launch platform. In 1982, it was decided that developing stealth technology would allow the ALCM to be replaced by an advanced version in 1986. This Advanced Cruise Missile (ACM) was to be subsonic, turbofan-powered and nuclear-armed like the ALCM. It was to incorporate more low signature "stealth" technology than the ALCM, however, and be somewhat faster and more accurate. It was claimed that this new missile would continue to enhance the longer-term effectiveness of the U.S. bomber force. Despite serious problems with quality control and reliability in its Tomahawk cruise missile program, General Dynamics was selected to build 1,400 Advanced Cruise Missiles to add to the existing ALCMs. In 1986, production of the ALCM was stopped at some 1,700 missiles, to allow more money to be spent on the ACM. Serious problems plagued the program, and, as a safeguard against continuing General Dynamics problems, in 1987, McDonnell Douglas was named as a second supplier of the missile. In July 1991, the Pentagon approved full-rate production of 1,000 ACMs (down from the original 1,461), based on improvements in test reliability. A classified "B" version of the ACM was also under development. Following the changes in the international situation, the ACM program was cancelled in January 1992 at the level of 640 missiles planned by that date; in June, it was reported that as a result of budget cuts, the total number of Advanced Cruise Missiles might reach only 270.

In June 1991, the Pentagon announced a $15 billion program to develop and purchase 8,650 conventionally-armed stealth cruise missiles. Known as the tri-service standoff attack missile (TSSAM), the missile would be capable of either ground- or air-launch, and would be used by all three military services. Its range would be between 185 and 500 kilometres, deliberately putting it outside the range of the INF and START agreements. Critics speculated

that plans for this missile were made public to increase the appeal of the controversial B-2 stealth bomber.

In the late 1970s and early 1980s, NATO strategic planning called for 464 GLCMs to be located in five Western European nations (160 in the United Kingdom, 112 in Italy, 96 in West Germany, and 48 each in Belgium and the Netherlands), together with 108 Pershing II intermediate-range ballistic missiles in West Germany. Deployment of these 572 missiles began in December 1983. Under the terms of the INF agreement signed in December 1987, these missiles were eliminated by the end of May 1991.

In the mid-1980s, the U.S. Navy planned to place SLCMs on four refitted World War II battleships, on nuclear-powered cruisers, on some air-defence cruisers and destroyers, and on certain nuclear-powered attack submarines -- about 4,000 missiles on almost 200 naval units by the mid-1990s. By 1991, 758 nuclear-armed SLCMs (which had entered service on American submarines and surface ships in 1984), were also to be deployed. By 1990, plans called for 3,630 Tomahawks; this included the 758 nuclear warheads, only one-half of which had been procured. In September 1991, the U.S. announced that it was withdrawing all naval tactical nuclear weapons, including SLCMs, from surface ships and submarines. The U.S.S.R. announced that it would follow suit on 5 October. Currently, the U.S. Navy is proceeding with the development and testing of the "Block III" upgrade for the Tomahawk. Due to be operational in 1993, the Block III upgrade will increase the range of the Tomahawk, improve its DSMAC system and allow the missile to make use of the U.S. Global Positioning System.

The United States holds a substantial lead over the Soviet Union (now Russia) in cruise missile development, in part because of its ability to package the technology more compactly. Nonetheless, in 1981 the U.S.S.R. began developing a new generation of long-range nuclear-armed air-, sea- and ground-launched cruise missiles. According to the U.S. government's *Soviet Military Power 1989*, in 1989 the U.S. and the U.S.S.R. were equal in terms of deployed cruise missile technology, although the U.S. had an edge in strategic systems and the U.S.S.R. an edge in naval systems; by the time *Soviet Military Power 1990* was released, the U.S. was credited with general cruise superiority.

The modern Soviet long-range cruise missile program is based on a missile similar to the American Tomahawk. With a range of roughly 3,000 kilometres, this missile was

produced in air-launched (AS-15), sea-launched (SS-N-21) and ground-launched (SSC-X-4) versions. (The SSC-X-4 ground-launched version was never deployed, and, like its American counterpart, was eliminated under the 1987 INF agreement.) The sea-launched SS-N-21, which entered service in 1987, has had technical problems with its guidance/propulsion systems according to U.S. intelligence, although a two-year improvement program was completed by 1990. Some 136 of these missiles were estimated to be deployed in 1990. U.S. intelligence sources also reported for years that the U.S.S.R. was working on a new, larger class of cruise missiles (the sea-launched version was designated the SSN-X-24 and the air-launched version the AS-X-19), but these seemed perpetually "in development." In late January 1992, responding to a range of unilateral and bilateral arms control initiatives, President Boris Yeltsin of Russia announced that production of all air- and sea- launched nuclear cruise missiles would end; according to reports, in 1992 the total inventory of nuclear-armed air-launched cruise missiles in Russia and Ukraine was 800, while the number of strategic naval cruise missiles was 240.

B. Cruise Missile Characteristics

Cruise missiles have a major advantage over rocket-powered missiles: since the cruise uses an air-breathing jet engine, it does not have to carry the oxidizer required by a rocket, giving it a much greater range for a given payload and weight of fuel. Otherwise, rocket-powered weapons are far faster, probably more reliable, have a lower radar cross-section, are simpler in their engineering and can use the same guidance systems as a cruise missile. The cruise missile has a Circular Error Probable (CEP) of some 30 metres; this means that half of all cruise missiles will fall within 30 metres of their target. This accuracy, coupled with its range advantage and the fact that cruise missiles were not covered in the SALT I agreement, made it a weapon of interest.

Beyond Mach 0.8 (80% of the speed of sound), the efficiency of the simple, subsonic turbofan engine declines and consequently the American cruise missiles described in this section are probably designed to fly at a speed not much greater than 885-965 kilometres per hour (550-600 miles/hour). A small turbofan engine has a cool exhaust and its infrared signature is correspondingly small. The missile's slow speed also means that there is little

surface heating due to friction with the air, again contributing to low infrared detectability. Flying at low altitude, cruise missiles are difficult for radar to spot in ground clutter: detection requires expensive systems with sophisticated processing capabilities. This complicates developing an effective defence against the cruise missile.

Table 1 describes certain characteristics of U.S. cruise missiles. Of particular interest are the missile guidance systems. All of the cruise variants are fitted with inertial guidance, a modern solution to determining the position of a moving vehicle. Unlike all other navigation systems, inertial guidance is self-contained and requires no external information. Given an initial orientation, the inertial system senses the motion of the carrier vehicle and uses that information to navigate by calculating changes in position. Inertial navigation is used on such vehicles as ballistic missiles, spacecraft and some commercial aircraft.

Because of its low airspeed, however, the cruise may require several hours to complete its mission. Even the best inertial systems will experience a sufficiently large drift over this period of time to cause unacceptable positional errors in the cruise missile's navigational fix. Thus the inertial system must be updated during flight by a correcting signal from some other form of guidance. TERCOM (terrain contour matching) has been selected as a supplemental navigational system for most land-attack versions of the cruise.

The earth's surface has been mapped by satellites and it is possible to create highly accurate three-dimensional maps of any land area. Such maps can be converted into a numerical grid and stored in the missile's guidance computer as a series of reference maps along a pre-programmed flight path. During the missile's flight, readings from an onboard downward-looking radar are periodically used to compare the terrain below with the stored topographic information. If the missile is off course, the computer searches the reference map for a better fit to steer the missile back to its preprogrammed path, updating the inertial guidance system in the process.

The TERCOM computer program uses a statistical criterion to compare the stored topographic information with the radar returns from the terrain being overflown. The flatter the terrain, the poorer the correlation and the greater the probability that the missile will wander in its flight path. Whether the cruise can navigate with a high degree of reliability over relatively

Table 1: Characteristics of U.S. Cruise Missiles

Missile(1)	Mission(2)	Warhead(3)	Launch Mode	Carrier	Range (miles/km)	Guidance(4)
ALCM (AGM-86B)	Strategic	Nuclear	Air	B-52/B-1 bombers	1550/2500	INS/TERCOM
ALCM (AGM-129A)(5)	Strategic	Nuclear	Air	B-52	/3000?	?
GLCM (BGM-109G)(6)	Tactical	Nuclear	Ground	Truck	1550/2500	INS/TERCOM
SLCM (BGM-109A)(Tomahawk)	Tactical	Nuclear	Sea	Submarine/surface ship	1550/2500	INS/TERCOM
SLCM (BGM-109C)(Tomahawk)	Tactical	Conventional	Sea	Submarine/surface ship	800/1300	INS/TERCOM/DSMAC
SLCM (BGM-109D)(Tomahawk)	Tactical	Conventional	Sea	Submarine/surface ship	800/1300	INS/TERCOM/DSMAC
SLCM (BGM-109B)(Tomahawk)	Tactical	Conventional	Sea	Submarine/surface ship	290/460	INS+

(1) The ALCM (86B) entered service in December 1982. GLCM deployment began in December 1983. The nuclear-armed SLCM (109A) entered service on both surface ships and submarines in Spring 1984; the conventionally-armed SLCM (109C) became operational on submarines late in 1982 and on surface vessels beginning in March 1983. The antiship SLCM (109B) appeared on submarines in November 1983 and on surface combatants in April 1984. All of the cruise missiles in Table 1 are powered by turbofan engines. Since the turbofan cannot propel a missile from rest, GLCMs and SLCMs need an initial rocket boost to accelerate to flying speed.

(2) Strategic and tactical applications are not clearly separated in all circumstances.

(3) The nuclear warhead is reported to be a 200 kiloton device in the ALCM and ACM and a 5-150 kiloton switchable device in the SLCM. Conventional warheads contain from 480 to 1,200 pounds of high explosives, depending upon the variant. In early 1992, it was revealed that a number of ALCMs had been modified to carry special conventional warheads.

(4) INS stands for inertial navigation system; TERCOM for terrain contour matching; DSMAC for digital scene-matching area correlator. "+" means there is supplemental precision guidance for terminal homing.

(5) Program development and procurement cancelled in January 1992.

(6) Banned under the 1987 INF Treaty - last U.S. GLCM destroyed May 1991.

Source: Modified from: Charles A. Sorrels, *U.S. Cruise Missile Programs: Development, Deployment and Implications for Arms Control*, McGraw-Hill Publications, Canada, 1983, fold-out chart at front of book.

featureless terrain remained to be demonstrated, and was one rationale for testing the cruise over northern Canada.

Conventionally armed cruise missiles are equipped with terminal homing systems to achieve even greater accuracy. One such system is the "digital scene-matching area correlator" (DSMAC) which compares stored optical or infrared data with information collected by the missile's sensors in the target area. The cruise can also employ radar or laser returns to fix on the target. Terminal homing provides improved guidance where the nature of the target or warhead requires delivery with extreme accuracy.

C. Future Cruise Missile Development

The United States has made major technical strides in cruise missilery but the Soviet Union worked vigorously to counter the American threat while developing its own strategic cruise variants. To preserve their advantage, the Americans continued to design more sophisticated strategic and tactical cruise missiles.

Future versions of the cruise missile can be expected to display higher speeds, greater manoeuverability, longer range, lower radar and other signatures, and penetration aids such as electronic countermeasures. An advanced version may be capable of taking evasive action in response to threats detected in flight (as distinct from pre-planned course changes stored in the guidance computer). A newer passive guidance system, called Autonomous Terminal Homing, and laser radars being tested under the Cruise Missile Advanced Guidance program could make cruise missiles more accurate and more difficult to detect. Some experts suggest that cruise missiles can be made capable of operating at supersonic speeds over intercontinental distances, allowing them to serve as strategic counterforce weapons against "hard" targets such as missile silos and command centres.

To achieve these goals, high-temperature turbofan engines with greater efficiency and higher thrust are being investigated. Exotic fuels such as boron and carbon slurries are being tested. To boost airspeed, other means of propulsion may be substituted for the turbofan engine. Composite materials could reduce airframe weight. TERCOM may be replaced by

other guidance systems promising better reliability and terminal homing systems will continue to be improved.

New cruise missile variants to perform other missions are also being studied. In the postwar period, the United States has stressed quality over quantity in its armaments, producing comparatively small numbers of highly sophisticated tactical aircraft for example. U.S. forces could not sustain high loss rates of such equipment in protracted battle, a situation made worse by the low readiness rates of such complex fighters as the F-14 Tomcat and F-15 Eagle. According to the Pentagon, if cruise missiles could assume some tactical missions of fighter aircraft in the modern battlefield (such as deep-strike interdiction or defence suppression), air forces would have greater staying power in sustained conflict.

D. Controversy Over the Cruise

1. Military Doctrine

The modern cruise missile appeals to many military analysts because of its broad range of application, its possible deployment in large numbers, its potential to combine quality and quantity in one weapon system, and its ability to be modified. Deploying the cruise also forces the enemy to make very costly improvements in its air defences. Nonetheless, the U.S. military establishment did not welcome cruise weaponry without strong reservations being expressed in some quarters.

New technology such as that embodied in the cruise cannot be considered apart from military doctrine. According to Richard Betts,

> ....A new weapon cannot be evaluated in isolation because its capability may be unnecessary or redundant. It must be evaluated (a) according to mission requirements and probable combat situations in terms of the three critical ingredients of military efficacy (mobility, striking power, and vulnerability) and (b) relative to the other elements of force posture...

Different versions of the cruise missile were supported with different rationales. The ALCM was justified as sustaining the role of the B-52 strategic bomber, one leg of the U.S. defence triad, by compensating for the declining ability of this aging, slow aircraft to penetrate

Soviet airspace. Although submarine-launched ballistic missiles now offer greater assurance than bombers of destroying "soft" targets, it was claimed that "cruise missiles offer a hedge against a Soviet technological breakthrough in antisubmarine warfare or an ABM [antiballistic missile] breakout." Cruise missiles, given their ability to destroy "hard" targets and the inadequacy of Soviet defences to cope with this new threat, helped offset a large Soviet advantage in ICBM throw weight. Strategic ALCMs in the opinion of some, therefore, helped close the "window of vulnerability" until other U.S. counterforce capabilities (the land-based MX and submarine-based D-5 ballistic missiles) became fully available. Also, a heavy Soviet investment in anti-cruise air defence constrained spending on offensive weaponry.

On the other hand, the slow-flying cruise would face increasing difficulty in penetrating air defence systems guarding prime targets, as the Soviets moved to counter this threat. While the ACM would complicate defence, it would also be a more expensive weapon for the U.S. to deploy. Furthermore, as the Soviet Union continued to install longer-range ALCMs and SLCMs on its own strategic platforms, a potential defence problem was created for North America (its formerly effective air defence system having been neglected when the primary Soviet threat shifted from manned bombers to ICBMs). In its Air Defence Initiative (ADI), the U.S. Air Force continued studying means of reinforcing North America's air defences to counter the new threat raised by Soviet longer-range cruise missiles.

Use of the SLCM in naval warfare raised its own set of questions: on what vessels should the sea-launched cruise be deployed; what is its relationship to carrier air power; and should the SLCM be developed for both strategic and tactical missions? In the aftermath of the INF agreement, a wide-ranging debate began over the role of SLCMs in compensating for missiles removed from Europe.

More recently, as the Soviet threat has declined, arguments have been made that the cruise is an ideal weapon for standoff strikes against targets in "out of area" locations and in lower-level conflicts. The successful use of Tomahawks in the Persian Gulf in early 1991 implies that this rationale will continue. According to Vice-Admiral James Williams, U.S. Deputy Commander of Naval Operations, "TLAMs (Tomahawk Land Attack Missiles) are an integral part of all our campaign plans. They must not be seen on their own."

Relating new technology to military doctrine is not academic. If large sums were to be spent to procure thousands of cruise missiles in various forms, this would be at least in part at the expense of other weapon systems.

2. Arms Control

It is apparent that cruise missile deployment complicates the task of arms negotiations. As Richard Betts wrote in 1981,

> Since the mid-1970s, expectations about the degree to which arms control agreements with Moscow can alleviate Western security problems have declined markedly. The disillusionment is due in part to the deterioration of détente and in part to the belief that the negotiation process cannot cope with the pace of technological innovation. The U.S. cruise missile and the Soviet Backfire bomber, for example, unraveled the 1974 Vladivostok agreement.... Although ALCMs were eventually accommodated within SALT II, that treaty took seven years to negotiate, and then was not ratified. If negotiations are revived, the decision to modernize NATO long-range theater nuclear forces with GLCMs may make a SALT III even more difficult...

Insofar as intercontinental forces are concerned, cruise missiles are a comparatively small element; the megatonnage which ICBMs and SLBMs (submarine-launched ballistic missiles) can already deliver is overwhelming.

Some analysts argue that dispersing such weapons at sea provides a more survivable nuclear force and hence increases superpower stability; critics maintain that turning many submarines and surface combat ships into potential nuclear launching platforms makes arms control a "horrendous" problem. In 1991, after the INF and START agreements, the issue of cruise missiles was a large one. Long-standing U.S. resistance to SLCM limits, for example, prevented progress on naval arms control, although agreement was reached on "politically binding declarations" for nuclear SLCM deployments in May 1990. Under the START agreement, it seemed likely that cruise missiles would become an increasingly important element in superpower strategic arsenals. On 27 September 1991, President Bush announced that all naval tactical nuclear weapons would be removed from ships and submarines and placed in

"central storage areas" in the United States. On 5 October, President Gorbachev announced that the U.S.S.R. would take similar measures.

3. Performance

Apart from military doctrine and arms negotiations, reservations have been voiced regarding the performance of the cruise missile. Testing and development are still underway and it remains to be seen how well performance will meet originally predicted capabilities. In a report to Congress in early 1981, the U.S. Comptroller General observed that:

> To date [January 1981], there have been no Government flight tests of the Ground Launched Cruise Missile. Operational tests of the air launched missile, still in progress, have revealed some serious problems relating to its (1) ability to maintain flight levels that would minimize radar detection, (2) terrain contour mapping guidance, and (3) reliability. The same problems are presumed to apply to the other two [ALCM and SLCM] missiles [because of their similarity in design].

The report further stated that none of the cruise missile systems had received sufficient testing prior to deployment and might subsequently require costly modifications to overcome operational limitations. ALCM testing had not been operationally realistic, with TERCOM having only been evaluated over terrain much rougher (and therefore easier to navigate with a terrain-following system) than that characterizing likely combat missions; and the reliability of the ALCM's fully integrated mission system was not adequately assessed prior to initial ALCM operating capability. The GLCM became operational before the U.S. Air Force had a chance to refine the launch system and deployment tactics. Defence officials in turn argued that overcoming shortfalls in strategic capabilities warranted taking some risks in these highly concurrent programs.

Similar problems have been identified with the Tomahawk program. According to a 1988 GAO report, significant problems were found to exist in Tomahawk "test planning and execution," "test realism" and "test analysis and reporting." Many of these criticisms appear to have been put to rest by the first operational use of Tomahawks, which took place in the Persian Gulf in early 1991. According to the Pentagon, over 100 Tomahawks were fired from surface ships in the early hours of operation Desert Storm, "against a variety of targets where

their precision was required for the target, or where, because of the air defence system around those targets, we felt that an unmanned weapon was the best system to use," according to American General Colin Powell, Chairman of the Joint Chiefs of Staff. Several days later, the USS *Louisville* became the first submarine to fire a Tomahawk operationally.

According to post-war reports, some 288 Tomahawks were used in the war against Iraq: 276 fired from surface ships and 12 from submarines. The accuracy of the Tomahawks was high, although critics insist that the media too readily accepted unverified U.S. claims for Tomahawk accuracy. The U.S. Navy has submitted a supplemental budget request for 301 SLCMs to replenish its stocks. During a period of heightened tensions, Tomahawk cruise missiles were launched against a target in Iraq in January 1993.

In the case of the newer ACM, success in early flight tests "hovered at about 50%" according to a Congressional report - "clearly an unacceptable rate for a major commitment to production." Congress warned that unless the results dramatically improved, the program faced cancellation. By early 1990, the ACM had completed 13 of 21 tests successfully, and production was scheduled to begin in fiscal 1992. In July 1991, approval was given for full-rate production of 1,000 AGM-129A ACMs, although orders for fiscal year 1992 depended on "substantial improvement" in the production quality of certain components and reliability improvement goals for the program. The Pentagon also ordered that planning include an option for up to 500 more ACMs, perhaps reflecting uncertainty over the effects of the recent START Treaty on U.S. strategic forces. The cancellation of further development and deployment of the ACM program at its planned level of 640 missiles was announced by President Bush in January 1992. By early 1992, some 100 ACMs were deployed and assigned to B-52H bombers at K.I. Sawyer Air Force Base in Michigan.

4. Political Developments

European missile deployment is considered by many to have been a major foreign policy success for the Reagan Administration and an important demonstration of NATO solidarity in the face of a strenuous Soviet campaign of intimidation. There is support for the view that the Soviets were surprisingly inept in confronting NATO over this issue, with heavy-handed meddling in European politics (especially during the 1983 West German election)

and ill-conceived threats (leading even Japan to support NATO missile deployment when the Soviets announced the positioning of more SS-20s in Asia). But the price of success was high, with Soviet-American relations severely strained and with several Western European leaders left to cope with serious domestic political problems.

In December 1979, NATO announced that in order to counter Soviet deployment of SS-20 ballistic missiles, it would follow a "two track" approach of both seeking an arms control solution to the problem and of placing Pershing II and ground-launched cruise missiles in Europe. The three countries crucial to NATO's missile deployment reaffirmed their commitment to the strategy in 1983, despite public protests across Western Europe which peaked on 22 October 1983. The British Parliament confirmed its decision on 31 October 1983, and the first 16 GLCMs were in place at Greenham Common air base the end of the same year. On 16 November 1983, the Italian Chamber of Deputies confirmed its support; Italy's first 16 GLCMs became operational at Comiso, Sicily in April 1984. The West German Bundestag approved missile deployment on 22 November 1983, and nine Pershing II missiles were operational at year-end 1983 at Swaebisch-Gmuend. A West German GLCM base was activated in the spring of 1985 at Wueschheim Air Station. After some hesitation, the Belgian Government voted to deploy the cruise on schedule, the Florennes Air Base receiving its first contingent of GLCMs in Spring 1985. The Dutch Government delayed a final decision on cruise missile basing until 1 November 1985. At that time the Dutch Cabinet approved deployment at Woensdrecht on the grounds that the Soviet Union had continued to deploy the SS-20. On 10 May 1984, the Danish Parliament voted to stop making its share of payments towards deploying the new NATO missiles. Denmark thus became the first member of the alliance to withdraw completely from the agreement to deploy the GLCM and Pershing II. In 1987, the INF Treaty was signed. It provided for the removal of intermediate-range nuclear weapons (including ground-launched cruise missiles) from Europe and their destruction by the end of May 1991.

5. Cruise Missile Testing in Canada

Following informal contacts between Canada and the United States on a weapons testing agreement, the two countries established the Canada/U.S. Test and Evaluation Program

in an exchange of notes on 10 February 1983. This agreement was for a period of five years and is automatically renewable for a period of a further five years. Either party may terminate the agreement by serving 12 months' notice. It was not reciprocal, anticipated cruise missile testing in Canada and stated that any such missile tested in this country shall be unarmed and that the use of Canadian civil airspace for cruise missile flights shall be controlled by the Minister of Transport.

On 13 June 1983, the U.S. Government requested approval to begin cruise missile testing in Canada in early 1984 and this request was approved on 15 July. In announcing that testing and evaluation of the Boeing AGM-86B ALCM could proceed, the Department of National Defence listed the following objectives for the project:

(a) Fly the AGM-86B over a route of realistic length and width with a representative standoff launch distance to the landfall.

(b) Fly the ALCM over relatively smooth terrain with various types of surface cover to include ice and snow.

(c) Operate the ALCM in operationally realistic weather conditions.

(d) Evaluate missile radar altimeter operation over snow, trees and ice-covered lakes.

(e) Evaluate effects of high-latitude operation on the navigation system alignment and missile launch.

(f) Obtain missile terminal accuracy information on an operationally representative route.

(g) Verify missile systems performance and vehicle aero- performance.

(h) Evaluate missile terrain-following and range performance.

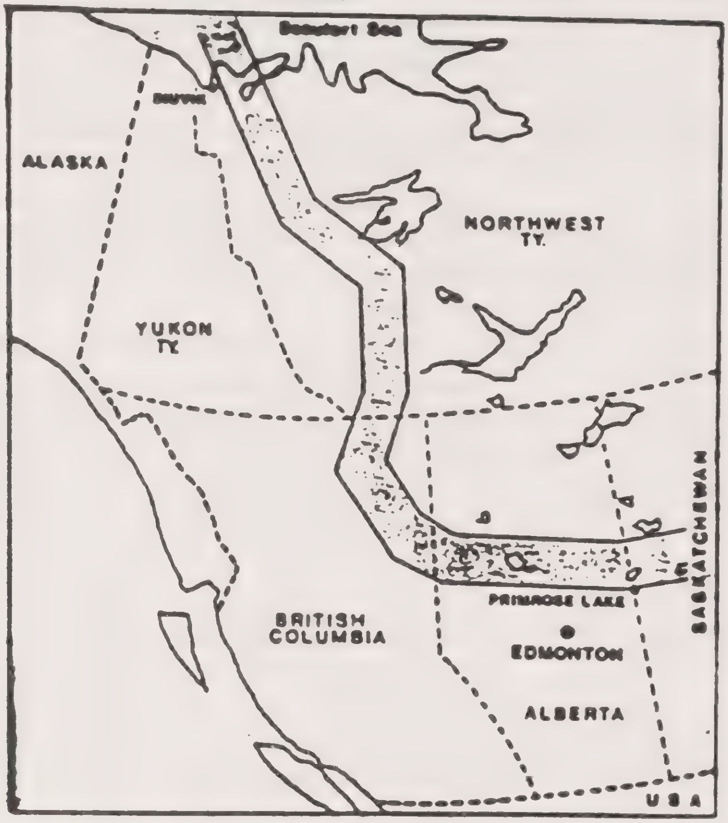
The 1,625 mile (2,600 km) test corridor -- which includes parts of the Northwest Territories, British Columbia, Alberta and Saskatchewan and which is outlined in Figure 1 -- could be used only during the months of January, February and March for flights in which the missile was launched from the B-52. "Captive carries," during which the missile remained attached to the bomber for the entire flight, were, however, not restricted to this time frame. No more than six ALCM launches could be conducted per year and operational testing of the

AGM-86B could continue for the term of the Canada-U.S. Test and Evaluation Program. Testing of any other version of the cruise missile required another project proposal and separate Government approval. In February 1989, the government agreed to allow the captive carry testing in Canada of the Advanced Cruise Missile (AGM-129A). The testing agreement was modified to allow seven tests per year in 1988, and extended until 1993. **In February 1993, the government announced that it had signed a renegotiated 10-year agreement with the United States.**

The tests conducted in Canada are complex, often involving 15-20 aircraft, from tankers to fighters to Airborne Warning and Control (AWACS) planes, in Canada and the United States. After the first several years of tests, attention shifted from monitoring the missile to attempting to track and intercept it - an important aspect of NORAD operations.

The first test of a cruise missile in Canada, a captive flight, was conducted on 6 March 1984; the first test of a stealth cruise took place on 2 March 1989. **To date, 23 cruise tests have been conducted in this country.** In January 1990, a test was designed to test the capability of Canadian CF-18 and U.S. F-15 and F-16 aircraft to intercept cruise missiles - an important part of the test regime. Upon takeoff, one of the Canadian CF-18s exploded, causing critics to renew their calls for an end to cruise testing in Canada. The issue of cruise missile testing in Canada has been a contentious one, with critics demanding the tests be halted as a contribution to arms control and the government arguing that cruise testing enhances deterrence and improves NORAD's anti-cruise capability. The most recent cruise test in Canada took place in March 1993.

Figure 1: The ALCM Test Corridor in Canada



The Canadian Test Route (shaded) is 1,400 n.m. long and 80 n.m. wide

Source: "Canada Agrees ALCM Test Route," *Flight International*, Vol. 124, No. 3876, 20 August 1983, p. 478.

CHRONOLOGY

June 1944 - Germans began attack on England with V-1 flying bombs.

1950s - The U.S. deployed crudely-guided cruise missiles with strategic forces but these proved too unreliable to compete with emerging ballistic missile systems. The U.S.S.R. introduced a series of naval cruise missiles to counter U.S. aircraft carrier forces and continued to refine these tactical missiles.

30 June 1977 - President Carter cancelled the B-1 strategic bomber program in favour of a large force of long-range ALCMs (some 3,400), to be deployed on B-52s.

18 June 1979 - The SALT II agreement was signed by President Carter and General Secretary Brezhnev. Although the U.S. Senate failed to approve the treaty, both sides declared that they would abide by its terms. A Protocol to the Salt II Treaty, which expired on 31 December 1981, contained two notable provisions:
(1) Each Party undertakes not to deploy cruise missiles capable of a range in excess of 600 kilometres on sea-based launchers or on land-based launchers.
(2) Each Party undertakes not to flight-test cruise missiles capable of a range in excess of 600 kilometres which are equipped with multiple independently targetable warheads from sea-based launchers or from land-based launchers.

12 December 1979 - Concern about Soviet deployment of the SS-20 ballistic missile prompted a NATO decision to modernize U.S. nuclear forces in Europe by introducing 108 Pershing II ballistic missiles into West Germany and 464 GLCMs into five Western European countries.

2 October 1981 - President Reagan proposed a five-year rearmament program which resurrected the B-1 strategic bomber.

14 October 1982 - The Litton Systems Canada plant at Rexdale, Ontario, a supplier of the cruise missile's inertial guidance system, was heavily damaged by a dynamite explosion.

December 1982 - The first squadron of 16 B-52s equipped with the ALCM became operational at Griffiss Air Force Base in New York State.

10 February 1983 - Canada and the United States agreed to the Canada/US (CANUS) Test and Evaluation Program. This agreement specified that cruise missiles, if tested in Canada, should be unarmed and that flight corridors in Canada to be used for cruise missile testing should be ected to ensure minimum disruption to civil aircraft operations and minimum disturbance to persons on the ground.

13 June 1983 -	The United States requested approval to test the air-launched cruise missile in Canada, under the terms of the Canada/US Test and Evaluation Program.
15 July 1983 -	The Federal Government announced it would allow U.S. testing of the Boeing AGM-86B ALCM in Canada.
end-December 1983 -	The first Pershing II ballistic missiles became operational in West Germany, together with the first GLCMs in Britain.
6 March 1984 -	The first test of the ALCM took place in Canada.
10 May 1984 -	Denmark became the first NATO member to withdraw completely from the agreement to deploy GLCM and Pershing II in Western Europe, terminating payments on its share of the deployment costs.
2 August 1984 -	The Soviet Union announced that it had conducted successful tests of long-range ground-launched cruise missiles.
25 February 1986 -	A cruise missile crashed immediately after launch from a B-52 when its engine failed to start. The missile crashed into the frozen Beaufort Sea northwest of Tuktoyaktuk, NWT. It was the eighth failure of an air-launched cruise missile in 54 tests. Immediately afterward, the federal government imposed a temporary halt on cruise missile testing in Canada under the 5-year Canada-U.S. agreement.
26 November 1986 -	The United States Defense Department announced that the 131st B-52 bomber equipped with cruise missiles would be flown to its operational base in Texas on November 28. This action exceeded the SALT-II limits for missile warheads and cruise-carrying bombers. Congress had formally asked President Reagan to adhere to the terms of the unratified treaty. The federal government expressed regret over the decision but said that cruise missile tests in Canada would continue.
8 December 1987 -	The INF Treaty was signed in Washington, with provision for the removal and destruction of ground-launched cruise missiles in Europe by 1991.

1 February 1989 - The federal government agreed to a request made on 17 January by the United States to test the new AGM-129A cruise missile over Canadian territory. The missile incorporates new stealth technology which makes it more difficult to detect by radar. Critics argued that the AGM-129A has a first strike capability against targets in the Soviet Union but the government maintained that the missile is strictly for retaliatory purposes.

May 1990 - Agreement was reached outside the START process for "politically binding declarations" on SLCM deployments.

January 1991 - First operational use of cruise missiles took place when Tomahawks were used in the Persian Gulf.

September-October 1991 - U.S. President Bush announced, on 27 September, that all naval nuclear weapons, including Tomahawk SLCMs, would be removed from ships and submarines and placed in "central storage areas" in the United States; on 5 October, President Gorbachev announced that the U.S.S.R. would take similar measures.

January 1992 - President Bush terminated development and procurement of the Advanced Cruise Missile at the planned level of 640 missiles.

January 1993 - Tomahawk cruise missiles were used against a target in Iraq.

February 1993 - Canada-U.S. Test and Evaluation Agreement renewed for another 10 years.

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